Tevatron-based Facilities beyond Run II

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Accelerator Advisory Committee Meeting

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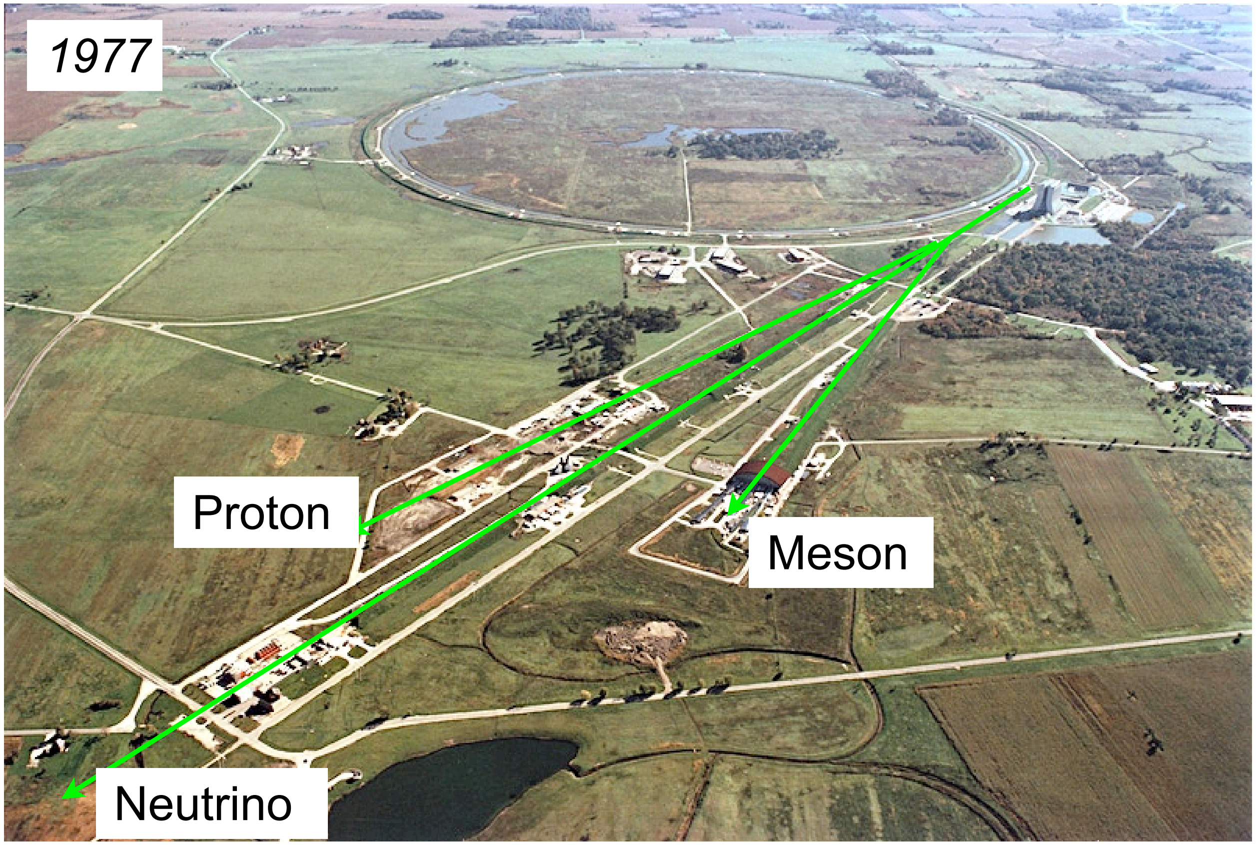
Fermilab

- Short history
- Present configuration for Fixed Target
- Two Options for after Run II
  - 120/150 GeV Fixed Target
  - 800 GeV Fixed Target

Fixed Target History

- Main Ring ran fixed target program until 1982
- Tevatron ran FT 1983-2000
  - shared time as Collider, ~50/50

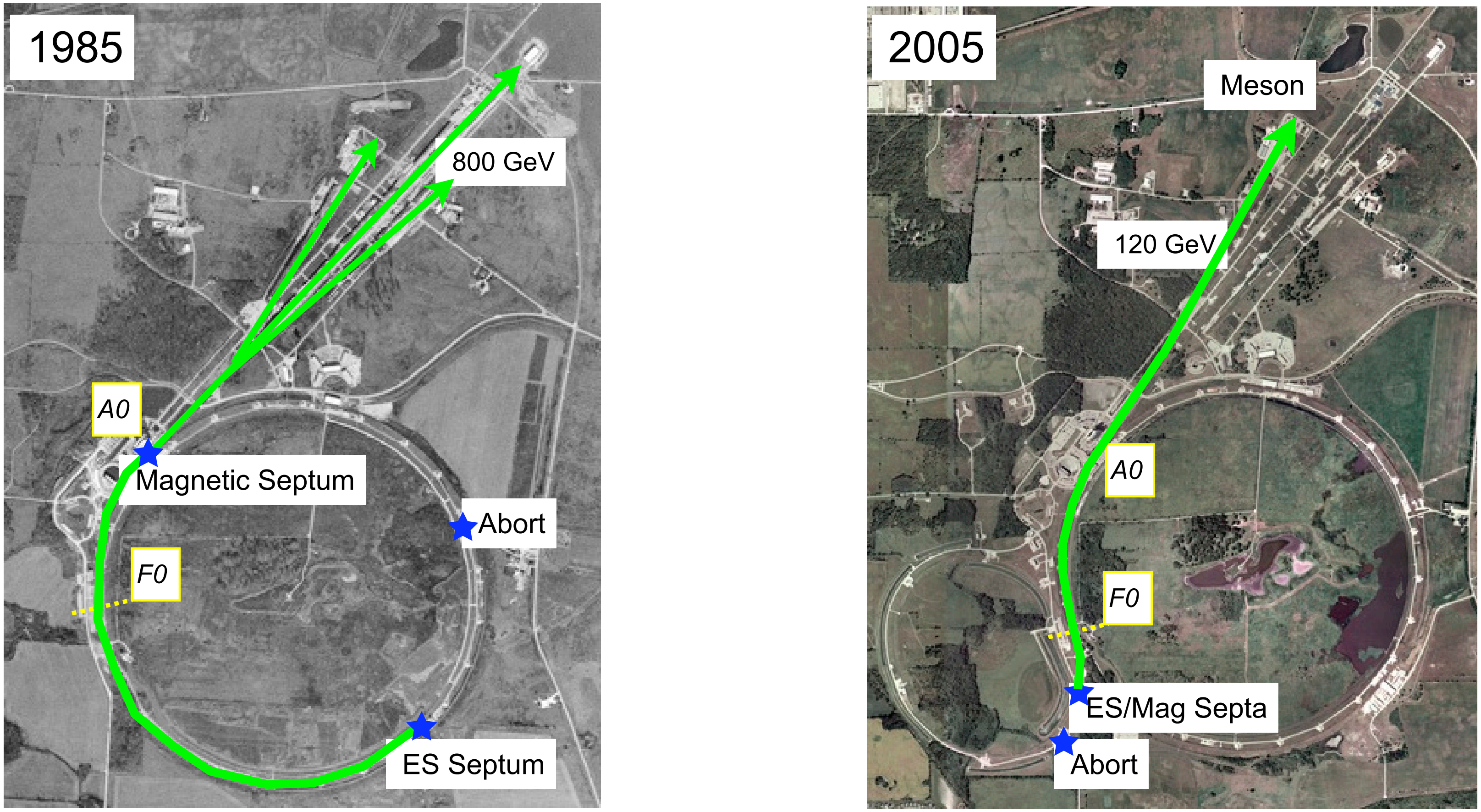


- MR: 400 GeV (typ.), 3×10^{13} ppp
- Tev: 800 GeV (typ.), $2\text{-}2.5\times10^{13}$ ppp
  - slow + fast resonant extraction

Enter Main Injector

- With the commissioning of the Main Injector, and the full push of the collider physics program, fixed target physics was relegated to 120 GeV from the new synchrotron.
- This program, dubbed Switchyard 120 (SY120), began operation in 2004.
- The "F0" straight section is the switch point
  - beam from MI to Tev is injected at F0
  - beam from MI to antiproton source passes through F0
    - then, through Tev tunnel to F17 location, and out to pbar
  - beam from MI to SY120 passes through F0
    - then, through Tev tunnel to A0, and out to Switchyard

pre-MI and post-MI FT Configurations



- MR/Tev: beam extracted from A0 straight section
- MI: transport to F0, thru MR remnant, to A0 and out...

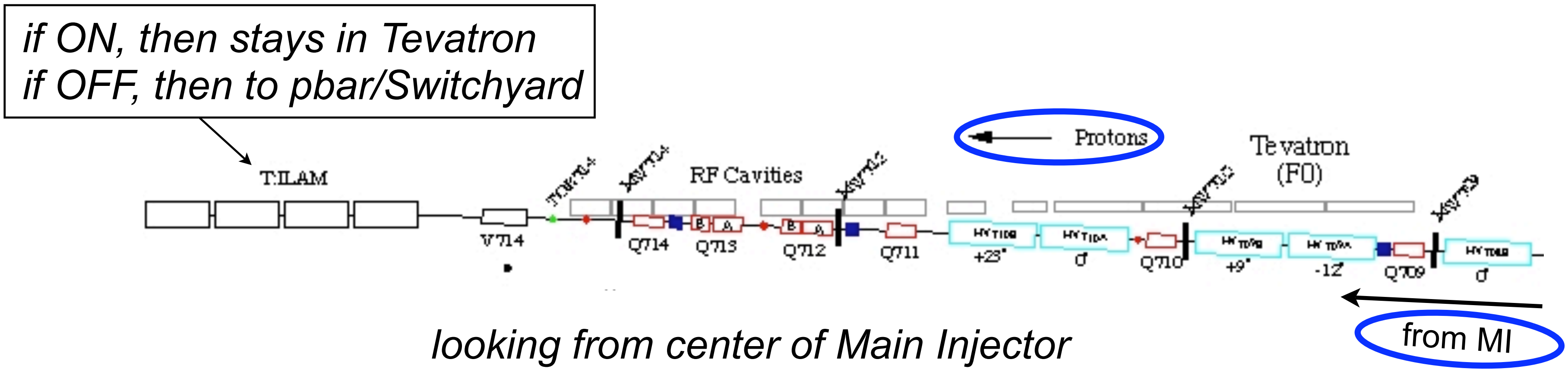
Tevatron Configurations

- pre-2000, would push/pull Fixed Target equipment with D0 detector, A0 abort
- C0 abort was proton-only; rated for high rate, high intensity fixed target operation.

	pre-MI FT	Run II Collider	
A0	Extr. Channel	Abort	<-- hi-β
B0	---	"CDF"	<-- low-β
C0	Abort	--- (BTeV)	
D0	ES septa	"D0"	<-- hi/low-β
E0	injection	instrum'tn	
F0	RF	RF / injection	

F0 Straight Section w/ Main Injector

- The Main Injector ties into the Tevatron tunnel at F0, where Tevatron RF cavities are also located

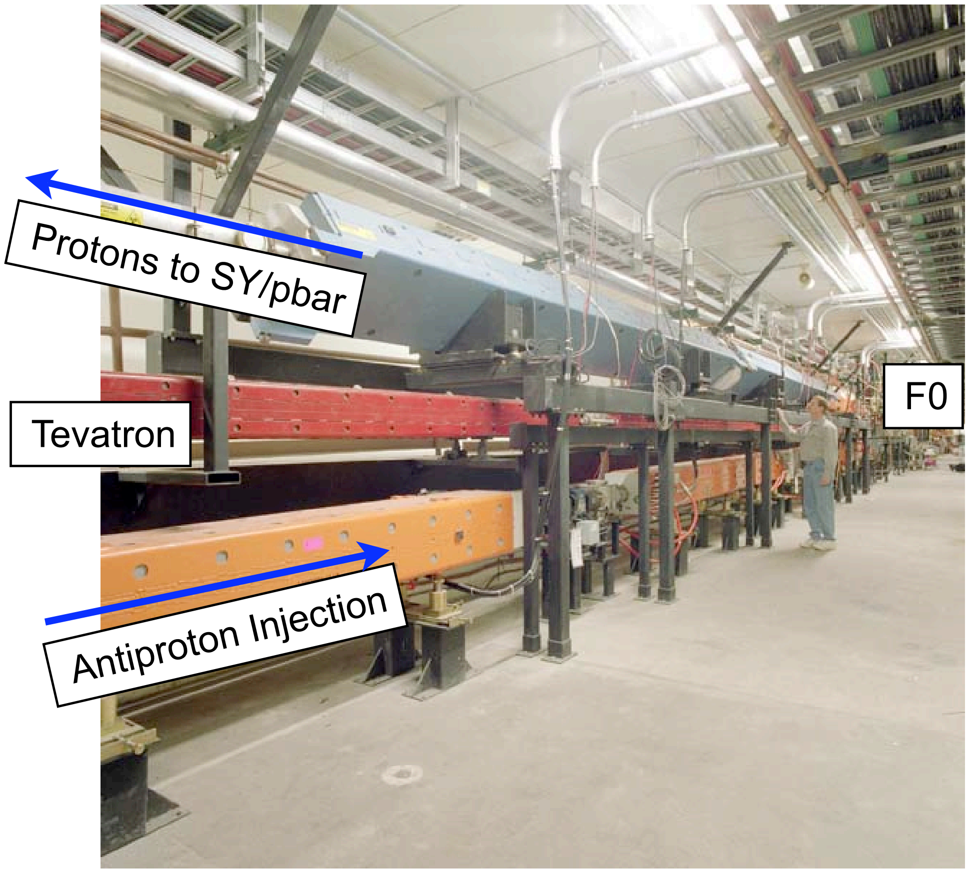


looking from center of Main Injector

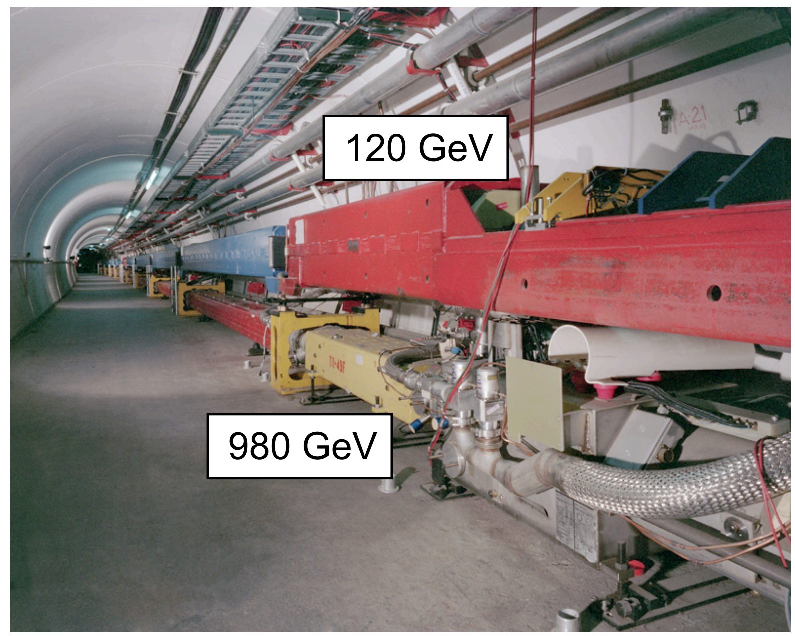
- Beam approaches injection magnetic septa from below; if septa are on, beam is deflected vertically and eventually kicked onto the Tevatron closed orbit; if septa are off, beam passes through and on toward either pbar source or to the SY120 beam line

Main Ring "Remnant"

- Remaining Main Ring elements are used to transport beam through Tevatron tunnel.



- Final Destinations:
  - F17 --> pbar production
  - A0 --> to Switchyard



Switchyard 120

- "Main Ring Remnant" is used to transport beam from F0 to F17 (for pbar production) and/or on toward A0 and the Switchyard/Meson Test Facility.
- SY120 beam line runs at 120 GeV, but with Power Supply upgrades could probably reach 150 GeV.
- Present Operation:
  - When running, typically pulse one 120 GeV ramp ~ every 2 mins.
  - ~1×10^{12} (1 Tp) spilled (slow resonant extraction) over a 4 sec flat-top
    - i.e., 250 Gp/s (peak), 8 Gp/s (ave), 3.3% d.f.

List of SY120 Users since MI

- List of Test Beam Memoranda of Understanding (MOU):

- T970: DHCAL Detector Research Under review
- T969: GammeV Under review (Magnet Test Facility)
- T968: T2K Muon Monitor Proto. Under rev. (MINOS hall)
- T967: Muon g-2 Calorimeter Test Signed
- T966: Monolithic pixel detector for ILC Signed
- T965: PSiP Photosensors **Experiment completed**
- T964: ILC GEM Chamber Characteristics Taking data
- T963: STAR Muon Telescope Detector Signed
- T962: Mini Liquid Argon TPC Under review (MINOS hall)
- T959: Microparticle Shielding Assessment **Completed**
- T958: FP420 Fast Timing Test Taking data
- T957: NIU Tail Catcher/Muon Test Taking data
- T956: ILC Muon Detector Tests Taking data
- T955: RPC Detector Tests Taking data
- T953: U. Iowa Cerenkov Light Tests Taking data
- T951: ALICE EMCAL Prototype Test **Experiment completed**
- T950: Vacuum Straw Tracker Taking data
- T945-Add. 1: Muon Veto Detector for COUPP Taking data
- T945: COUPP Bubble Chamber Taking data
- T943: U. Hawaii Monolithic Active Pixel Det. **Experiment completed**
- T941: UIowa PPAC Test **Experiment completed**
- T936: US/CMS Forward Pixel **Experiment completed**
- T935: BTeV RICH **Experiment completed**
- T933: BTeV ECAL **Experiment completed**
- T932: Diamond Detector Signed
- T931: BTeV Muon **Experiment completed**
- T930: BTeV Straw **Experiment completed**
- T927: BTeV Pixel **Experiment completed**
- T926: RICE **Experiment completed**

see... http://www-ppd.fnal.gov/MTBF-w/

Program Impact

- SY120 reflects small impact on other operations
  - very infrequent time line interruptions for 120 GeV ramps
  - one MI pulse (2.4 sec, say) in standard two minute time line: 2% hit on remaining program demanding beam from the Main Injector

- On other hand, may say that SY120 program **limited** due to the fact that it interrupts other higher-priority programs that demand beam from the Main Injector --
  - antiproton production, NuMI

A Unique Facility

- As the world's first superconducting synchrotron the Tevatron was able to deliver fixed target beams at nearly twice the particle energy of any other facility.
- While other SC synchrotrons have been built since, none have the ability to ramp rapidly to full field and thus support a viable fixed target program at particle energies near 1 TeV
- With the Collider Run II program end nearing, some are considering fixed target options again...
  - high statistics ν_μ scattering experiment (NusOnG)
  - Kaon physics
  - More demand for detector (e.g., ILC) test beams
  - ??

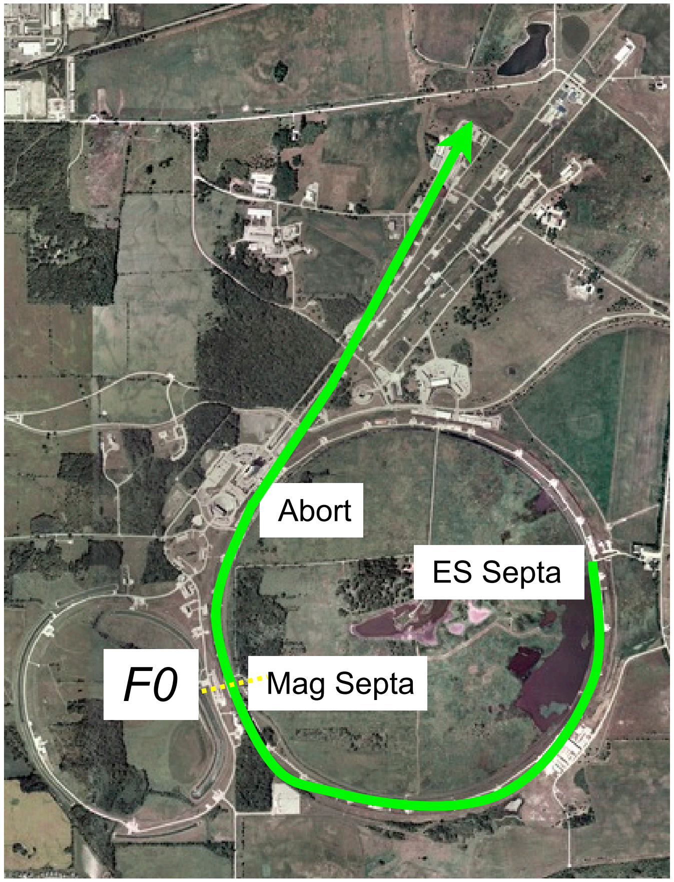
see: http://www.fnal.gov/directorate/Longrange/Steering_Public/documents.html

Two Fixed Target Options to Consider

- Option One --
  - Operate Tevatron as a “stretcher ring” to store and provide beam to the test beam facility, or to future experiments that can tie to the extracted beam line.
    - operate at injection energy of 150 GeV (and upgrade the beam line to SY150), or at 120 GeV
    - “easy” to implement almost immediately
- Option Two --
  - Resurrect high-energy (800 GeV) fixed target capability
    - though components still exist, would require more down time than Option One to implement
- Issues for both:
  - demands of experimental programs, and operating costs

TEV120-150

- Can use the F0 injection septum as an extraction septum (reverse its polarity after injection; needs a new polarity switch)
- Install electrostatic septum near F0, or perhaps C0
  - C0 -- presently "unused"
- resurrect slow-spill feedback system ("QXR")
  - fast air-core quadrupole mags
  - may wish to upgrade electronics



Performance Issues

- Is there room (aperture) for extraction at 120?
  - beam at 120 GeV is 2.5 times larger than at 800 GeV
  - however, 120 GeV extraction has been made to work in MI with similar aperture constraints
  - Tevatron **did** extract at lower energies (400 GeV) upon commissioning (1983)
  - Emittance through injector chain much better controlled today than during previous Fixed Target times; though "blown up" during extraction process, more room for generating necessary step size across septa
  - would need further verification, but not unreasonable to assume 120 GeV extraction could be made to work

Performance Issues at 120/150 GeV

- intensity limitations
  - Tevatron Fixed Target program ran at 20-28 Tp per pulse
  - limited by intensity dependent instabilities at higher energy (typ. ~ 600 GeV) as momentum spread reduced
  - Transverse impedance of Tevatron reduced during Run II
    - Lambertson Magnets identified as major sources, and beam tube liners introduced; greatly stabilized transverse motion
  - Also, 30 Tp was about limit of injector; today, the MI can deliver 40-45 Tp per pulse, and two pulses can be used to fill the Tevatron --> 80 Tp! Probably way too large, but could possibly consider 40 Tp as reasonable intensity goal at 120 GeV, and acknowledge higher intensities perhaps possible...

Performance Issues at 120/150 GeV

- Abort at A0 can handle it...
  - to extent that we equate 80 Tp @ 120 GeV with 10 Tp @ 980 GeV (today's Run II operation)
  - Naturally, fault conditions, etc., would need verificaiton
- Tevatron would be run DC at 120/150: no snap-back, tune drift, etc.; more quench margin
- Beam can be stored in Tev, and spilled "on demand" at different rates at different times
- Many/most fixed target users want smooth beam spill; could consider use of barrier buckets to get rid of 53 MHz component; or, pre-condition in the MI ahead of time. Many variants could be explored.

Performance Issues at 120/150 GeV

- Examples of possible particle rates, for comparison

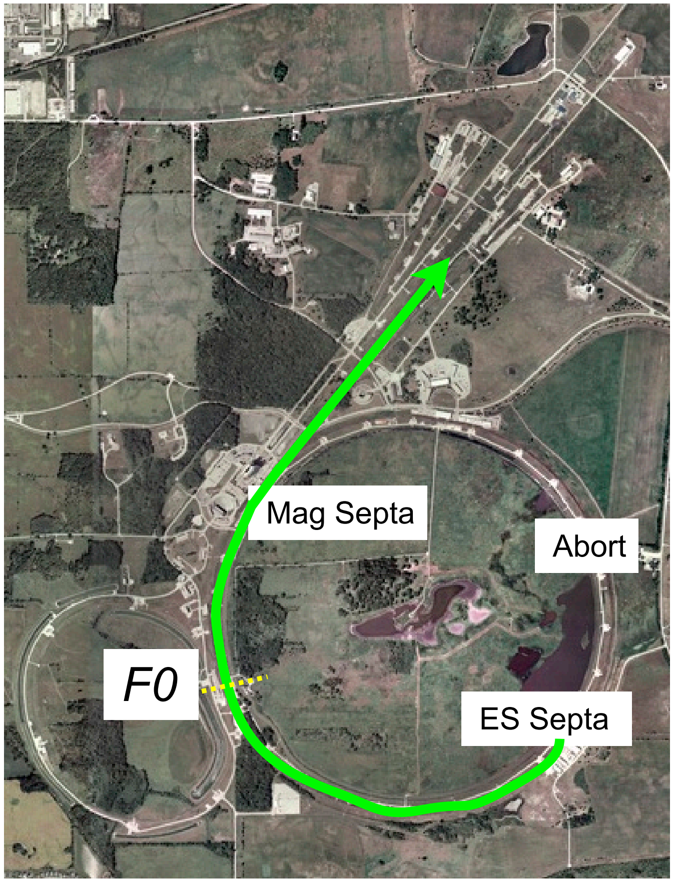
Present Operation

N_{max}	Cycle (sec)	dN/dt (Gp/sec, ave)	dN/dt (Gp/sec, max)	POT/yr (10^{18}/yr)	duty factor	hit on MI pgm
1 Tp (1 pulse)	120	8	250	0.17	3.3%	2.5%
30 Tp (15+15)	3600	8	8	0.17	99.9%	0.08%
30 Tp (15+15)	120	250	260	5	97.5%	2.5%
40 Tp (20+20)	60	660	700	14	95%	5%
50 Tp (1 pulse)	15	3300	4200	70	80%	10%

Scenarios assume 1.5 sec MI cycle, 3 sec in Tev for debunching and/or other “preps”; 66% of year operation

TEV800

- Proposed neutrino expt needs high enegy (~1 TeV)
- RF at F0 precludes extraction there; extract at A0
- Install electrostatic septum either near A0, or else at D0
- Extraction:
  - if fast res. extr., need "QXR"
  - perhaps could form few, long bunches and use kickers to avoid ES septa (??)
  - would work out exact scenario with the experiment



Performance Issues at 800 GeV

- We know that 800 GeV slow extraction works by design; however, intensity limitations at high energy were always an issue
  - today's high intensity limit at high energy unknown, following septum magnet beam tube upgrades, but should be improved over FT runs of past
  - also, beam damper systems much improved these days
    - But note: neutrino expt. proposal: 2.5x Tev record intensity
- Abort at C0 -- decommissioned with BTeV in sight
  - would need to re-commission extraction kickers (may need new pulse forming network) and extraction magnets
  - 28 Tp @ 800 GeV = 3.5 MJ; 75 Tp --> 10 MJ
  - need to re-examine inst. rates onto abort block, etc.

Performance Issues at 800 GeV

- Ramp-rate & magnet issues
  - Power Supplies and RF capable of delivering 55 GeV/s (used prev. in FT mode); may be desirable to upgrade some dump switch equipment in PS system
  - Magnets perhaps capable of higher rates
    - would need more RF; stick with standard rate
  - Neutrino program wants lots of beam in short amount of time -- i.e., pulses (or, "pings") rather than slow spill
  - Thus, use above ramp rate to make a 36-40 sec cycle, with a ~1 sec flat-top for extracting many (5-50) pulses

Performance Issues at 800 GeV

- Early FT running in 1980's resulted in many magnet failures
  - bus lead restraints within cryostat identified and fixed
  - since then, ~250,000 cycles between magnet failures
    - (this rate includes failures of non-standard Tev magnets)
  - Note: neutrino exp wants 1.5e20 POT w/ 7.5 TP/cycle
    - --> ~2 millions cycles ---> ~8 failures likely
  - need to either have enough spares to last through the experimental program, or re-institute capabilities of repairing or constructing magnets
- If 8-12 failures is the right scale, then enough spares should exist for the NusOnG experiment

Performance Issues at 800 GeV

- Particle Extraction
  - In previous FT running, typically 60 sec cycle, with ~25-28 Tp/pulse, spilled over a 20-23 sec flat-top, giving roughly a 33-40% duty factor
  - During slow resonant extraction, beam was "pinged" ("fast" resonant extraction) to the neutrino experiments
  - May be that few, long bunches could be formed in Tev (or prepped in MI) and then could be kicked out with kicker magnets (kick out 8 bunches of 10 Tp each, say)
    - Single-turn extraction was cleanly performed (test conditions) in Tevatron w/ 10 Tp.
  - If only 1-2 neutrino experiments in Switchyard, then would deliberate the extraction method depending upon the needs of the users -- both methods seem feasible

Summary

- A first look at two possible Fixed Target Options:
  - 120/150 GeV "stretcher ring"
  - 800 GeV FT redux, for neutrino program
- Stretcher -- "easy" to implement; fast turn-around time; SY120 program/beam line exists; Kaon program may need higher intensities -- yet to be demonstrated, but not out of question
- Neutrino Beam -- much to re-install, but mostly still exists; hi-intensity an issue, needs addressing (we know Z/n is better, but good enough? dampers? beam loading?   abort system adequate?)

Summary -- 2

- As stated before, Tevatron is a unique facility for providing high energy fixed target beams
- Before dismantling the Tevatron and its infrastructure, should be sure that it truly has lived out its useful life
- Both options: could use more formal study/review; may wish to perform some beam/paper studies in near future to further ensure the feasibility of these options
- Further reading:
  - http://beamdocs.fnal.gov/AD-public/DocDB/ShowDocument?docid=2849